Experimenting with a Touch-Tone DTMF Receiver

By Forrest M. Mims III

In recent years, semiconductor companies have introduced various integrated circuits capable of generating and decoding the Touch-Tone™ signals used in pushbutton telephones. Since Touch-Tone signals can be easily transmitted over wires, radio waves, beams of light, and through the air as sound waves, the new chips permit the signals to be used in many kinds of remote-control applications.

For example, ICs that decode Touch-Tone signals make possible receivers capable of responding to signals sent over the telephone line. Lights or appliances at any location equipped with a telephone and such a receiver can be switched on or off by pressing buttons on a second telephone equipped with a Touch-Tone keypad. If the second telephone is not equipped with a Touch-Tone pad, then the signals can be transmitted by means of a commercial or homemade Touch-Tone circuit placed next to the telephone's handset microphone.

The dual-tone principle of a Touch-Tone system requires that two specified tones be simultaneously present before an output signal is generated at the receiver. This greatly reduces the impact of interfering signals and means Touch-Tone encoders and decoders can be used in non-telephone applications which might be subject to interference from externally induced signals.

Several years ago experimenters and hobbyists who wished to experiment with Touch-Tone signals were forced to assemble the required circuits from scratch. Integrated circuits capable of generating Touch-Tone signals, such as the crystal-controlled MC14410 tone encoder, greatly simplified the assembly of such circuits.

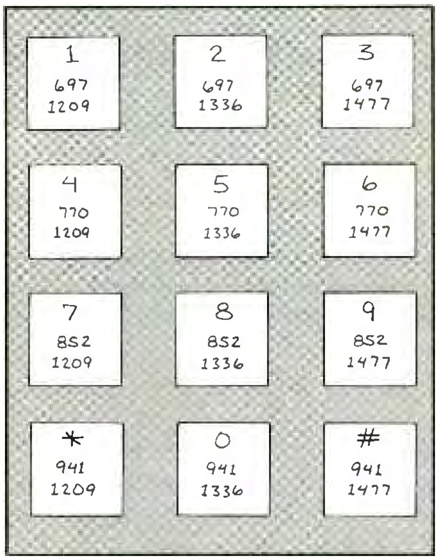


Fig. 1. Each key of the Touch Tone keypad selects two tone frequencies as shown. Selections are made from seven available frequencies.

Today, it's possible to buy preassembled, pocket-size Touch-Tone encoders for less than the cost of assembling a do-it-yourself unit. For example, Radio Shack sells a compact Touch-Tone generator complete with batteries for less than $20. More expensive units include such features as memory, digital display and crystal controlled clock.

Commercial Touch-Tone decoder systems are not as widely available or as economical as encoder units. At least not yet. Therefore, the emphasis here will be upon the operation of a particularly versatile decoder chip suitable for do-it-yourself circuits, the Teletone Corp. M-957. Before looking at this chip in some detail, however, let's quickly review the basics of the Touch-Tone system.

Touch-Tone Basis

The Bell System invented the Touch-Tone system specifically for pushbutton telephones. The keypad on a typical pushbutton phone includes 12 buttons, 10 labeled 0 through 9 and two special functions keys, known as spares, labeled * and #. The system can be expanded to include four additional keys.

Pressing a Touch-Tone button generates two simultaneous audio-frequency tones. Figure 1 shows the frequency pair assigned to each button. The four additional keys would control an eighth tone having a frequency of 1633 Hz.

The technical term for the various Touch-Tone frequencies is *Dual-Tone Multifrequency* (DTMF) signals. If you refer to Fig. 1, you'll observe that the seven frequencies seem arbitrary and rather oddly distributed. Actually, the frequencies were very carefully selected to reduce to a minimum interference from voice, the dial tone, and the harmonics from alternating current power lines.

The frequencies are divided into a low group (697 to 941 Hz) and a high group (1209 to 1477 Hz). Pressing any button simultaneously selects one frequency from each group. Since both tones must occur simultaneously, the possibility of a false signal is negligible. This is why a DTMF system should be considered for remote-control applications that might be subject to false triggering from noise or interfering signals.

For instance, a few years ago I designed a radio-controlled camera system for making aerial photographs from kites and balloons. (See the "Experimenter's Corner" in the November and December 1982 and January 1983 issues of *Computers & Electronics*.) This system was triggered by single-frequency audio tone superimposed on the carrier of a low-cost radio-control transmitter.

With this system, I have obtained many good-quality aerial photos. Unfortunately, the system is very vulnerable to false triggering, as have been most remote-control systems I have built that use a single-frequency. In other words, it can sometimes be triggered by ship-to-shore radios and CB units in passing cars and trucks. Now that I have experimented with DTMF circuits, I plan to modify my aerial photography system for Touch-Tone operation. The system should be virtually immune to false triggering and it will provide the added bonus of up to 16 channels.

IC DTMF Receivers

Several companies make chips that receive and decode DTMF signals. Among them are Mitel Semiconductor (2321 Morena Blvd., Suite M, San Diego, CA 92110); Silicon Systems, Inc. (14351 Myford Rd., Tustin, CA 92680); and Teltone Corp. (P.O. Box 657, Kirkland, WA 98033).

The DTMF receiver chips made by these companies all incorporate switched-capacitor filters to detect the transmitted tones. The filter stages are followed by various kinds of amplitude detection circuitry and logic that determines when two detected tones are present. Each chip includes an output decoder that transforms the detected tone into a binary bit pattern. CMOS IC circuitry is generally used to provide low-power operation.

Teltone DTMF Receiver

Teltone has for several years made available to hobbyists and experimenters a line of reasonably priced DTMF receiver kits. The latest is the TRK-957 DTMF Receiver Kit, which sells for $24.75. It includes an M-957 CMOS DTMF receiver, a 3.58-MHz crystal, a 1-megohm resistor and a 22-pin DIP socket. You can order the kit by writing the company at the address given above or by calling (800) 227-3800, extension 1130. (Inside California, call 800-792-0990.)

Figure 2A is a photo of the plastic version of the 22-pin M-957. A more expensive version of the chip is available in a ceramic package (CERDIP), while Fig. 2B is its pinout diagram. Pin placements are similiar, though not identical, to those of the M-947, an earlier DTMF receiver which was once sold in a Teltone kit. The M-957 is very easy to use so long as operating requirements and precautions given in the manufacturer's data sheet are followed. Since the M-957 is a CMOS chip, it's important to observe proper handling procedures to avoid damaging the chip with high-voltage static electricity.

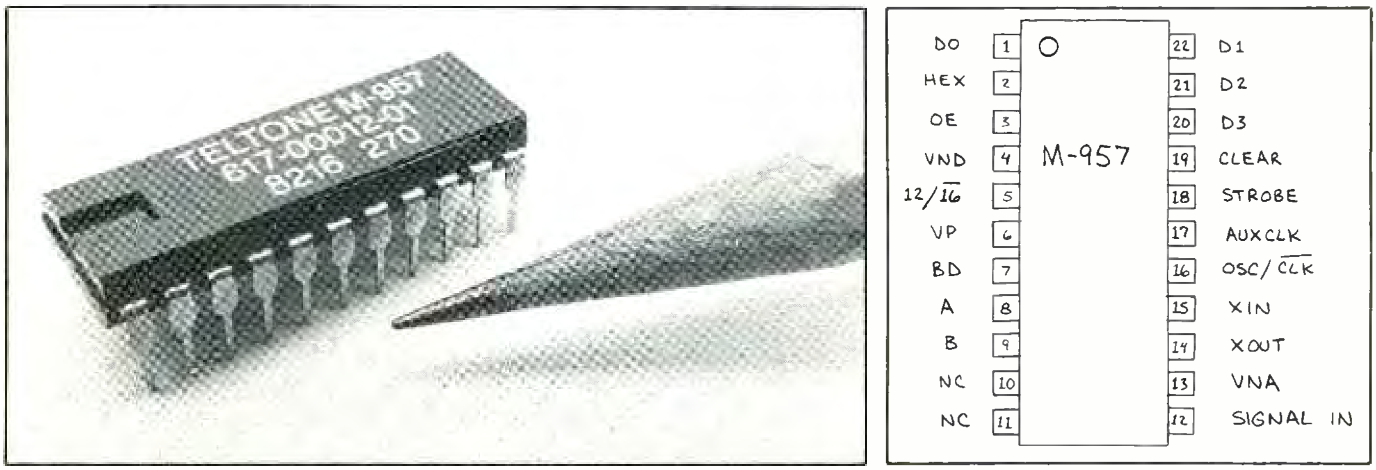
Referring to the pin diagram in Fig. 2B, the positive supply, which should be from +5 volts to an absolute maximum of +16 volts, is applied to the M-957 at pin 6 (VP). Pins 4 (VND) and 13 (VNA) should be at ground potential.

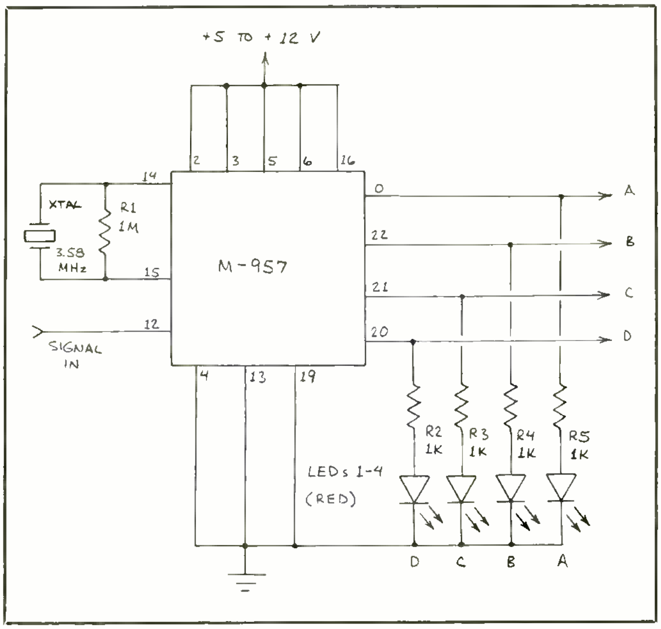
The DTMF signal is applied to the M-957 at pin 12 (SIGNAL IN). The input signal may be ac coupled through a capacitor. If the signal is dc coupled, the peak signal voltage must not exceed the positive supply voltage. Therefore, the input signal should always be removed *before* power to the M-957 is switched off.

A 3.58-MHz crystal and a 1-megohm resistor are both connected across pins 15 (XIN) and 14 (XOUT) to provide a precise timebase for the chip's internal oscillator. If the internal oscillator is not used, pin 15 should be tied to logic 1.

Pin 16 (OSC/CLK) is the timebase control. When pin 16 is at logic 1, the internal oscillator is selected. When pin 16 is at logic 0 (and pin 15 is at logic 1), a signal applied to AUXCLK is selected as the timebase. Pin 17 (AUXCLK) should be left open when the internal timebase is selected (pin 16 at

Fig. 2. At the left is a photograph of the Teltone M-957 DTMF receiver integrated circuit, while at the right is a drawing that shows the IC's pin function designations.





SIGNAL	LOW TONE	HIGH TONE	BINARY OUTPUT	2-OF-8 OUTPUT
1	697	1209	0001	0000
2	697	1336	0010	0001
3	697	1477	0011	0010
4	770	1209	0100	0100
5	770	1336	0101	0101
6	770	1477	0110	0110
7	852	1209	0111	1000
8	852	1336	1000	1001
9	852	1477	1001	1010
0	941	1336	1010	1101
*	941	1209	1011	1100
#	941	1477	1100	1110
A	697	1633	1101	0011
B	770	1633	1110	0111
C	852	1633	1111	1011
D	941	1633	0000	1111

Fig. 3. This is the schematic diagram of the M-957 Touch Tone decoder test circuit in which LEDs give visual indication of the circuit's operation.

logic 1). If an external signal is used for a timebase, its frequency must be 3.58 MHz divided by 8 or the M-957 integrated circuit will not decode signals properly.

The M-957 has four output pins (1, 22, 21 and 20) conveniently grouped at one end of the chip. As explained below, these pins provide two kinds of binary bit patterns that correspond to the detected DTMF signal.

Several control and output pins add to the M-957's versatility. The 12/16 input (pin 5) determines which range of DTMF signals will be detected. When pin 5 is at logic 1, the standard 12 DTMF signals of the pushbutton telephone will be detected. When pin 5 is at logic 0, all 16 DTMF signals are detected.

The A and B inputs (pins 8 and 9) control the sensitivity of the M-957 to the input signal. Applying various combinations of logic states to these two pins adjusts the sensitivity in steps to a maximum of −31 dBm.

The OE input (pin 3) is controlled whether the output pins are enabled or placed in the high-impedance or so-called third state. When pin 3 is at logic 1, the output pins are enabled and represent the contents of the M-957's output register. When pin 3 is at logic 0, the output pins are placed in the high-impedance third state.

The HEX input (pin 2) controls the format of the four output pins. When pin 2 is at logic 1, the output pins provide a standard 4-bit binary bit pattern. When pin 2 is at logic 0, the output pins provide a 2-of-8 binary code. The table summarizes the two output modes of the M-957.

The STROBE input (pin 18) indicates when a valid frequency pair is present at the input. Normally, pin 18 is at logic 0. When a valid frequency pair has been detected, pin 18 goes to logic 1 until the signal ends or the CLEAR input (pin 19) is placed at logic 1. If the CLEAR input is not used, it should be tied to ground (VNA or VND) to prevent stray signals from causing inadvertent clear operations.

Output BD (pin 7) provides an early indication of a possibly valid DTMF signal at the input pin. Normally BD is at logic 0, but it goes to logic 1 when a signal has been received and is being validated. The BD output responds to an input signal within about 18 milliseconds while the STROBE output requires about 40 milliseconds to verify a correct signal.

Using the M-957

Figure 3 is a straightforward test circuit for the M-957. The input signal may be supplied directly from a Touch-Tone keypad, a tape recorder, an amplifier, or a radio receiver so long as the signal amplitude does not exceed the positive supply applied to the M-957. The signal may be coupled directly (dc) or through a 0.01-μF capacitor (ac).

The circuit in Fig. 4 includes four optional LEDs connected to the outputs to provide a visual indication of the received signal. Indicator LEDs can also be connected to other outputs of the M-957.

Generally, it's desirable to decode the binary output from the M-957 into a 1-of-16 format. Figure 4 shows how to connect a 74C154 4-line to

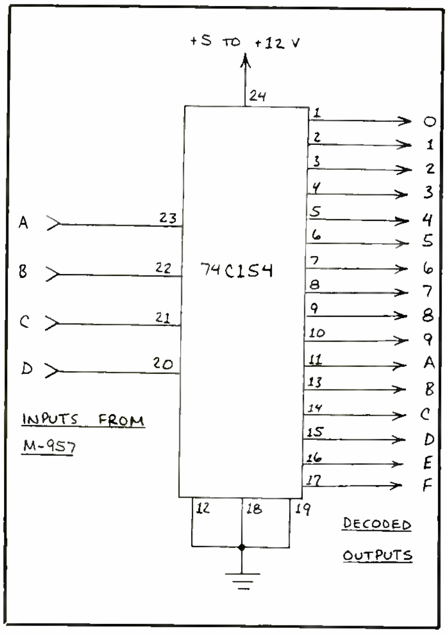


Fig. 4. This is a 74C154 1-of-6 decoder for use with the M-957 Touch Tone decoder integrated circuit.

16-line decoder to the outputs of the M-957 to achieve this purpose. Keep in mind that the 74C154 is a CMOS chip and should be handled accordingly. Other CMOS decoder chips can also be used.

Figure 5 shows how to drive a relay from one of the outputs from the 74C154 or a similar decoder. Diode *D1* absorbs reverse voltage generated by the collapsing field in the relay's coil when the relay is switched off. The relay is normally deenergized. When the base of *Q1* is placed at logic 0, the relay is energized. If the circuit doesn't switch consistently, try making slight changes in the value of *R2*.

I have had excellent results experimenting with the M-957 in a variety of non-telephone remote-control applications. Those readers wishing to connect the chip directly to a telephone line will want to first carefully review the M-957 data sheet. Figure 6 is adapted from a suggested telephone line interface circuit given in the M-957 data sheet. If this single-supply circuit doesn't work properly, try using a dual-polarity supply. In other words, connect pin 4 to the negative counterpart of the positive supply instead of to ground.

It's very important that you understand the interfacing requirements imposed by your local telephone company before connecting a do-it-yourself circuit to their lines. The Federal Communications Commission allows customer-provided equipment to be connected to telephone lines if the equipment meets FCC guidelines. In every case, the equipment must be connected to the lines with standard four-prong or modular telephone plugs and jacks. Check your telephone directory for guidelines and call the company if necessary.

Going Further

As you can see by now, the familiar Touch-Tone DTMF signals have far more applications than merely dialing telephone numbers. For more information, write the manufacturers whose addresses are given above and request data sheets and application notes. Also, look for articles on DTMF applications and new encoder and receiver chips in the various electronics and communications magazines available at most good university libraries.

If your primary interest is connecting circuits to the telephone line, be sure to thoroughly research the topic and proceed with caution. An excellent book for hobbyists is "Electronic Telephone Projects" by Anthony J. Caristi (1979, No. 21618, Howard W. Sams & Co.). **ME**

Fig. 5. Relay driver circuit for the decoder IC chip.

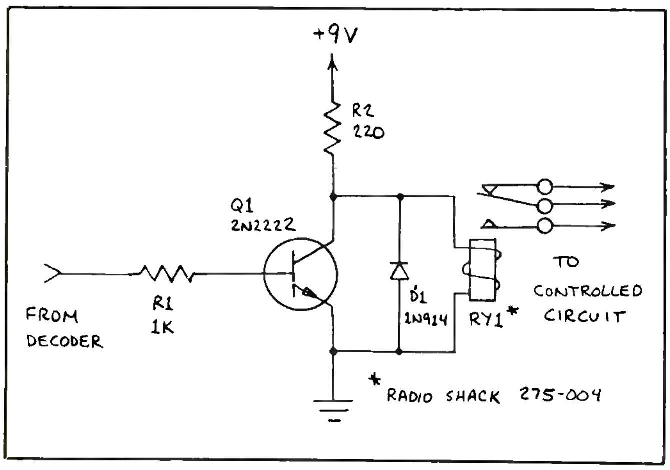


Fig. 6. Tone-decoder telephone-line interface circuit.